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RIVER QUALITY AND INDUSTRIAL ADJUSTMENT: A CASE STUDY

*By Frank C. Emerson**

The interaction of water quality in the Kalamazoo River Basin with the regional paper industry is described. The improvement of the Kalamazoo River, which had been called the most polluted river in Michigan, has come about as a result of a mix of pollution-control measures and changes in industrial operations. These have included the establishment of a major joint municipal-industrial wastewater treatment facility and a decline in the recycling of lower grades of wastepaper for the production of higher-quality paper.

The Kalamazoo River Basin runs west for about 50 miles from south central Michigan near the Ohio boundary to the city of Kalamazoo, where the River turns northwest and flows 70 miles to its mouth near Saugatuck on Lake Michigan. Apparently, fishing on the River was relatively good until the early part of the 20th century, when the paper industry, which had been located in the Kalamazoo area since the 1860s, underwent a major expansion. Principal products of this complex included printing papers for the publishing industry in Chicago and paperboard for use in cereal boxes in nearby Battle Creek.

All paper mills were located adjacent to the Kalamazoo River or one of its major tributaries. By 1950, eight different companies owned ten sites in the area, with some sites having as many as three mills. Fifteen hundred tons of paper and paperboard, approximately 2% of U. S. output, were produced daily. The manufacture of paper or paperboard requires approximately 48,000 gallons of water (in the absence of in-plant water recycling), and most mills used the River as a source of process water. More significantly, all mills were, in effect, using the River as a free sewer for the disposal of wastewaters bearing a large load of inorganic and biodegradeable materials.

Perhaps the only respite from the growing pollution load was the general installation by the paper industry, beginning around 1940, of "savealls."¹ These are basically air-injection flotation tanks

which permit the separation of reuseable fibers from the "whitewater" in which they are carried. Reuse of water from a saveall permits the profitable recapture of a number of chemical additives and contributes to a reduction in the mill's energy consumption since recycled water does not need to be heated from river temperatures to the production temperature on the order of 160 degrees Fahrenheit. Water which is continuously reused does, however, acquire a substantial loading of organic matter, so that the wastewater discharged to the River contained a relatively high concentration of biochemical oxygen demand (BOD).

I. PAPER RECYCLING AND THE RIVER

Historically, the American paper industry was located in the northeastern and Great Lakes states in order to make use of the native softwoods. As this resource became scarcer, the industry made increasing use of paper wastes from nearby urban areas as raw material. Since World War II, however, there has been a decline in the proportion of waste paper recycled. In order to be closer to large supplies of pulpwood, including lumber mill residues, and to exploit the economies of scale available in large integrated pulp and paper operations, most of the new papermaking capacity was located in the forests of the South and Northwest. The kraft pulping process had turned the fast-growing southern softwood forests, in particular, into a ready source of cheap pulpwood. Many of the new mills owned a portion of the forests which supplied their pulpwood. Capital gains treatment for harvested pulpwood further increased the profitability of using wood rather than wastepaper in mills located away from urban sources of recyclable fiber. Wastepaper remained an economically competitive source of fiber principally in non-integrated mills located near major urban areas.

The recycling of wastepaper does, however, have the potential for reducing the impact of paper and paperboard production on a number of aspects of environmental quality. First, it may modestly reduce pressure on national forests which are increasingly used for commercial purposes.² Second, to the extent that useable fiber can be cheaply separated from other wastes and delivered to mills, some costs of urban solid waste disposal can be avoided. Third, to the extent that wastepaper can be substituted for virgin fiber, a net reduction in air and water pollution is possible, particularly where wastepaper is recycled into lower grades of paper and paperboard.

The pollution load generated by paper recycling depends, to a great extent, upon which sorts of wastepaper (paperstock) are made

into which sorts of paper and board. In principle, paperstock of virtually any quality can be made into products having high and low quality specifications. Most low quality paperstocks are, however, used in the manufacture of paperboard. In this process, it is possible to essentially bake a large part of what would otherwise be a wasteload of fine fibers and inorganic solids into the inner layers of the paperboard. The fibers yielded by the low grade paperstock can subsequently be covered by a visually pleasing outer liner.

High quality paperstock generally has a low content of contaminants such as ink or other chemicals and is usually sorted according to grade. However, this paperstock typically commands market prices which are not far below those for virgin pulp since it is cheap to process and is thus a very close substitute for virgin fiber. In order to effectively recycle wastepaper into high quality printing and writing paper, lower grades of paperstock must be "de-inked." The de-inking process which removes ink and other contaminants from paperstock, does, however, produce a notoriously dirty wastewater which requires extensive treatment in order to avoid the creation of a potentially large pollution problem.

The comparative environmental impact of manufacturing high quality paper from virgin pulp and de-inked wastepaper can be seen in Table I. The increased recycling change in Table I is significantly less adverse in the manufacture of low quality paper using non de-inked wastepaper as regards: (1) process water used (-61); (2) BOD discharge (-44); (3) suspended solids discharge (-25); (4) process solid wastes (-39); and (5) net post consumer waste disposal (-129).³ On the Kalamazoo River, a large portion of the heavy pollution load resulted from the more than 600 tons of paperstock which was de-inked daily in order to produce high quality printing and writing paper. In fact, in 1950, the three principal de-inking mills in the Kalamazoo area accounted for 62% of the BOD discharged into the River.⁴ A particularly heavy solids wasteload resulted from the recycling of magazines, which contain clay and other coatings comprising up to 40% of their weight. These additives improve opacity and printability, giving the paper a gloss. Whereas clay, for example, was useable in the lining of paperboard, it was essentially dumped into the River at de-inking mills.

By 1950, the River, which had an average flow of 800 cubic feet per second, was receiving approximately 350,000 pounds of solids each day. The accompanying BOD load of approximately 100, 000 pounds per day was equivalent to that of the untreated domestic waste of a city of 500,000 people.⁵ At that time, the population of

TABLE I

ENVIRONMENTAL IMPACTS RESULTING FROM THE MANUFACTURE OF
1,000 TONS OF BLEACHED VIRGIN KRAFT PULP AND EQUIVALENT
MANUFACTURED FROM DEINKED AND BLEACHED WASTEPAPER

Environmental effect	Virgin fiber pulp	Deinked Pulp	Increased recycling change (%) a
Virgin materials use (oven dry fiber)	1,100 tons	-0-	-100
Process water used	47,000 x 10 ³ gallons	40,000 x 10 ³ gallons	-15
Energy consumption	23,000 x 10 ⁶ BTU	9,000 x 10 ⁶ BTU	-60
Air pollutants (transportation, manufacturing, and harvesting) b	49 tons	20 tons	-60
Waterborne wastes discharged - BOD b	23 tons	20 tons	-13
Waterborne wastes discharged—suspended solids	24 tons	77 tons	+222
Process solid wastes	112 tons	224 tons	+100
Net post-consumer waste disposal	850 tons c	-550 tons d	-165

a Negative number represents a decrease in that category resulting from recycling.

b Based on surveys conducted in 1968-1970.

c This assumes a 15% loss of fiber in paperworking and converting operations.

d This assumes that 1,400 tons of waste paper is needed to produce 1,000 tons of pulp. Therefore, 850-1,400 = 550 represents the net reduction in post-consumer solid waste.

Source: Midwest Research Institute. Economic studies in support of policy formation on resource recovery. Unpublished data, 1972.

Kalamazoo, which did not have any waste treatment facilities, was under 70,000. One description of the river downstream of the downtown area reported, “. . . there was much evidence of septic action. Gas eruptions from the water gave the appearance of splashes of raindrops all about. Chunks of sludge, varying in size up to that of a platter, were raised from the bottom of the river by gases”⁶ The banks of the River were lined with a sludge composed of clay and organic matter.

These septic conditions reached their peak during the hot summer months when dissolved oxygen readings were typically zero in the entire reach of the river between Kalamazoo and Plainwell, about 10 miles downstream from the paper mills. There are numerous verbal reports of the annual appearance of a mysterious “black fungus” on houses painted with white lead-based paints, which was

attributed to the generation of hydrogen sulfide in the River. Some Plainwell residents would sleep with their windows closed on hot summer nights in order to avoid the odor. In the Plainwell area, the wasteload in the River was further augmented by discharges from three more paper mills, one of which included the only pulping operation (sulfite process) in the Valley. Some twenty miles downstream of Plainwell, at Allegan, there were reports of silverware tarnishing as a result of hydrogen sulfide from the River.⁷ Perhaps the most noteworthy incident was a major fish kill at Lake Allegan (approximately forty miles downstream of Kalamazoo) which rated photographic coverage by Life magazine in 1953.⁸ By this time, wastes had given the River a greyish appearance and impaired the quality of fishing on the Kalamazoo all the way to its mouth at Lake Michigan, some seventy miles downstream of Kalamazoo.⁹

II. IMPROVEMENTS

A. *First Round*

In the early 1950's, after several studies¹⁰ and under pressure from the Michigan Water Resources Commission, the mills were required to install primary treatment facilities for their effluents. (Primary treatment is usually accomplished in a clarifier, which is essentially a large tank in which undissolved solids are allowed to settle into a sludge. The sludge is usually dried or subjected to anaerobic digestion before being buried.) By a majority of 86%, Kalamazoo voters authorized a \$2 million bond issue in order to construct an "intermediate" sewage treatment facility consisting basically of clarifiers and a scum-removal unit. Principally as a result of the clarifier installations, the growth of sludge (mostly clay) deposits along the banks of the River was abated, but the problems associated with the BOD load persisted.¹¹

B. *Second Round*

Agitation for improving the River continued, additional studies were made;¹² and, in the early 1960's, the Water Resource Commission issued BOD discharge quotas, which initially required that each major discharger reduce its BOD wasteload by approximately 70%.¹³ It was calculated that this reduction would protect the River from the severe disruptions caused by a high BOD load during periods of low flow. Faced with the possibility of constructing individual secondary (biological) treatment plants, the mills expressed an interest in the joint treatment of their wastes and city wastes.

At this point, it is worthwhile pointing out that an essentially equiproportional reduction in discharges by a group of polluters virtually guarantees that the desired reduction will not come about in the least expensive manner. Costs per unit discharge reduction are unlikely to be equal for all activities discharging into a river, and unit costs are likely to be highest for reducing the smallest discharges. Thus the achievement of a given discharge reduction on a segment of a river is likely to be accomplished most efficiently by bringing about large discharge reductions at major sources and smaller reductions, or perhaps none, at sources of small discharges. One way to do this would be to assign discharge quotas to sources of pollution (by whatever means), and then allow those assigned quotas to bargain among themselves. A not unlikely outcome could be that a source of a small discharge (having a small quota) would find it worthwhile to make payments to a source of a larger discharge for reducing its pollution by an amount *in addition* to that required of it. The additional discharge abatement carried out by the large source would equal the discharge reduction required of the smaller source.

At Kalamazoo, the majority of industrial facilities opted to use joint treatment facilities rather than establish individual secondary treatment facilities. Perhaps the most obvious benefit of joint treatment is the possibility for the exploitation of economies of scale, i.e., lower costs per unit treated in larger facilities. Sewage plants appear to have construction costs characterized by the so-called "engineer's 6/10 rule" which states that costs vary approximately as the 6/10 power of the volume of flow handled, so that, for example, doubling the volume of flow would increase construction costs by about 50%.¹⁴ Since there is a fairly wide variation over time in the volume of individual discharges, and since facilities should be equipped to handle peak loads, a single large facility is able, in effect, to pool peak capacity requirements. Thus, the ratio of peak (design) flow to average flow can be lower in a joint facility, further reducing costs per unit treated. Since any single effluent stream becomes a smaller proportion of the total flow in a larger facility, a joint plant tends to be less subject to "upsets" arising from shock loadings of strong wastes or the accidental inflow of wastes which are toxic to the organisms upon which biological treatment depends. In addition, the joint treatment of nutrient-deficient industrial wastes, which are high in BOD, and domestic wastes, which are typically relatively low in BOD and high in nutrients, reduces the cost of treatment by making the usual additions of nutrients to industrial wastes unnecessary.

The cost advantages of joint treatment do, however, tend to be limited by the costs of collecting wastes, since, in order to increase the volume treated at a particular facility, wastes have to be moved to the plant over successively greater distances. An additional problem, important in some cases, is that a large facility may impose an extremely heavy load on the receiving waters at a single point, thereby not using the assimilative capacity of the river as efficiently as would be the case if a number of smaller discharges were distributed along the river. Moreover, since industrial and domestic wastes are mixed, the entire flow must be chlorinated before discharge in order to control possible disease-bearing bacteria.

It is often noted that municipal facilities tend to be of somewhat more substantial construction than are industrial waste-control facilities handling similar loads. To some extent, the apparently better construction of municipal treatment plants is probably explainable by the lower cost of capital to municipalities via grants and tax-exempt bonds, creating an incentive to substitute "cheap" capital for city-borne operating and maintenance expenses.¹⁵ A highly suggestive example is that, of the four municipalities in the Kalamazoo area which perform at least some secondary treatment, *all* make use of concrete structures for activated sludge or trickling filter processes. Of the four paper mills which perform all of the treatment of their wastes (sending none to the joint facility), *all* perform their biological treatment in either aerated earthen basins or earthen settling ponds.

Construction of the secondary treatment plant at Kalamazoo was begun before increased federal subsidies for waste treatment facilities were authorized in 1966.¹⁶ To date, however, the plant has received federal grants amounting to well under 25% of the total construction cost of the \$4.6 million secondary treatment facility.¹⁷

The joint waste treatment facility at Kalamazoo was opened in 1967 and made use of the previously existing treatment units plus new activated sludge aeration basins. Charges for industrial use of the facility are based upon the distance the waste is moved, effluent flow, BOD, and solids content. There is a higher flow-related charge for wastes which must be given primary treatment at the facility. Since no part of the facility is owned by industry, the operating costs are recovered through specific charges for waste treatment. A portion of the city property tax is used to retire bonds issued for plant construction. Industries outside of the city which use the facility pay charges based upon the content of their discharges plus a charge equivalent to the city property tax used for retiring bonds issued for

the joint facility. Since the opening of the facility, a number of smaller suburban communities have contracted for city treatment of their sewage.

No discussion of the pollution abatement activities at Kalamazoo would be complete without mentioning the notorious "sludge pits." When the improved facility was opened in 1967, arrangements had been made to concentrate sludge from the plant in a number of lagoons located on a hilltop at the eastern edge of the city. Publicly stated opinions on the matter vary, but there was apparently a change in the waste load characteristics between the time of the initial planning for sludge thickening and the operation of the lagoons.¹⁸ In any case, when the sludge was pumped to the lagoons, the mixture went anaerobic, subjecting a substantial portion of the east side of the city to a powerful odor. There were public protests and complaints and finally a court order was issued requiring a bond issue for the construction of in-plant wet sludge combustion, concentration, and incineration equipment. A number of temporary measures to control the odor were taken, including covering one two-acre lagoon with a plastic sheet. Odor problems at the sludge pits were finally terminated in 1972 when the in-plant sludge disposal system was installed. Perhaps the ultimate irony of the history of grants to the Kalamazoo facility is that federal and state funds have already covered over 65% of the cost of the extremely advanced \$4.4 million sludge-combustion facility. But, as noted, less than 25% of the cost of the "basic" secondary treatment plant has been reimbursed to date.¹⁹

While a great deal of the waste discharge reduction can be attributed to activity initiated by the City and the Water Resources Commission, it appears that much of the river improvement would have taken place without public policy action because a major source of discharge reductions has been the decline of paper recycling in the river basin. To a large extent, as a result of the increasing use of additives in paper, particularly certain dyes, latex, asphalts, and plastic, it has become costlier to produce recycled pulp of a quality which will yield paper comparable with that produced from virgin fiber. The combination of increased costs of de-inking, increased scarcity of cheaply recyclable paperstock, prohibitive cost of hand sorting waste paper, and cheap virgin woodpulp, particularly from new facilities in the Southeast, has led to a decrease in the proportion of paper which is recycled in the United States.²⁰

Recycling for use in fine and book papers at Kalamazoo has fallen dramatically. De-inking at one mill—which produced 15% of the

BOD discharged in 1950 — ended in 1964 when the company opened a new pulp mill in the South. All operations at this mill have since ceased entirely. De-inking has recently been discontinued altogether at two other fine paper mills which continue in operation using virgin pulp and very high (clean) grades of paperstock. Another de-inking mill, which was the smallest of the paper operations in the area, has also been closed. Only one mill continues de-inking on a relatively modest scale. However, an informal survey by the author indicated that waste treatment costs were decisive in *none* of the mill closings.

Five paper companies now make use of the joint treatment facility. The two paperboard operations provide primary treatment for their effluent, and are able to recycle the clarifier underflow for use in the product. The smallest of the surviving papermaking operations, a fine paper mill, has closed its clarifier and now sends its entire untreated wasteload to the City facility. Since firms discharging wastes into the River are required by the state to monitor and report their discharges, and the cost of this is likely to be at least a few hundred dollars per month, monitoring costs may have been decisive in the choice of joint treatment by companies having small wasteloads. The one maker of fine papers which continues de-inking operates a clarifier and sends the clarified effluent to the City while operating its own sludge thickening basins. A current agreement provides, however, that in event of a malfunction of the clarifier, de-inking will be discontinued in order to avoid overloading the municipal plant. Another company operates two smaller mills which have stopped de-inking. These mills send their effluent to a common clarifier, operate sludge basins, send a portion of their clarified effluent to the City, and continue to discharge a portion of their wastewater (albeit within state imposed limitations) into a tributary of the River. The single paper operation located downstream of the municipal plant and two miles away is able to meet discharge limitations through on-site treatment in earthen basins. The joint treatment facility now accepts the wastes of a large pharmaceutical manufacturer, which has been able to reduce the size of its on-site treatment plant.

Conclusion

After over 20 years of construction and industry-state-municipal bargaining, the quality of the Kalamazoo River has markedly improved. The River is no longer a source of odors, the water is more visually pleasing, and there are even occasional reports of game fish

(which fare poorly in flavor tests) in the reach of the River below Kalamazoo.²¹ The joint municipal treatment plant, where industry wasteflows account for roughly two thirds of the effluent treated, appears to be workable.

A variety of changes have contributed to the decline in total waste production by the regional paper industry. These include mill closings, shifts in input mixes and production processes used, and better control of effluent discharges. Ironically, the major reduction in the pretreatment wasteload has come about as a result of the decline in the use of recycled paper for the production of fine writing and printing papers.

FOOTNOTES

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¹See, Bower, G.O.G. Lof, and W. M. Hearon, *Residuals Management in the Pulp and Paper Industry*, NATURAL RESOURCES J. 2:4:605-23, (Oct. 1971), for a brief discussion of savealls.

²In 1970, the Public Land Law Review Commission recommended that the most productive federal timber lands be classified commercial and be managed so as to maximize federal income from them. Council on the Environment of New York City, A DISCUSSION: GOVERNMENT INCENTIVES AND DISINCENTIVES TO RECLAMATION OF WASTE PAPER, at 29-30, (March, 1973).

³CONGRESSIONAL REPORT TO THE CEQ ON RECYCLING, at 10, (G.P.O. 1973).

⁴Citizens Study Committee on Kalamazoo River Waste, REPORT OF FINDINGS OF THE CITIZENS STUDY COMM. ON KALAMAZOO RIVER WASTE, at 16, (Sept. 1951).

⁵*Id.*

⁶*Id.* at 15.

⁷KALAMAZOO GAZETTE, April 19, 1970, at 22.

⁸LIFE, Oct. 5, 1953, 35:27.

⁹KALAMAZOO GAZETTE, April 19, 1970, at 22.

¹⁰Eldridge, E.F., A STUDY OF PAPER MILL WASTE DISPOSAL AT KALAMAZOO VALLEY PAPER MILL, (Michigan Engineering Experiment Station, 1944); and Surbe, E.W. and A. Corcoran, INTERIM REPORT OF A BIOLOGICAL SURVEY OF THE EFFECTS OF POLLUTION IN THE KALAMAZOO RIVER, (U.S. Pub. Health Service and Michigan Water Resources Commission, 1951).

¹¹Michigan Water Resources Comm., REPORT ON SELF PURIFICATION CAPACITIES: KALAMAZOO RIVER, at 4, 18, (March, 1958).

¹²See, *Id.*, and M. Pirnie Engineers, Inc., REPORT ON LOW FLOW

REGULATION OF THE KALAMAZOO RIVER, (Kalamazoo Intermunicipality Study Comm., Dec. 1958).

¹³M. Pirnie Engineers, Inc., ECONOMIC FEASIBILITY OF JOINT WASTE DISPOSAL IN KALAMAZOO COUNTY (Dec. 1961).

¹⁴See, Smith R., *Cost of Conventional and Advanced Treatment of Wastewater*, 40 WATER POLLUTION CONTROL FEDERATION J., 1546-74, (Sept. 1968).

¹⁵See, Foster J.H., DECISION FACTORS IN COMBINED TREATMENT PROBLEMS, TECHNICAL ASPECTS OF JOINT WASTE TREATMENT, at 42-50, (U. Mass. Press, 1969). Also, see, Sanders, F.A., *Decision Factors — Separate Industry or Joint Municipal Waste Treatment*, 23RD INDUSTRIAL WASTE CONFERENCE PROCEEDINGS, at 1021-28, (Purdue U. 1968).

¹⁶Clean Water Restoration Act of 1966, Pub. L. 89-753.

¹⁷PULP AND PAPER, at 58, (Feb. 1971).

¹⁸PUBLIC WORKS, at 90-1, (Aug. 1971).

¹⁹PULP AND PAPER, at 58, (Feb. 1971) and informal communications with a city official.

²⁰Forsythe, J.J., RECYCLING OF PAPER, Tappi, 55:5:679-90, (May, 1972). In 1944, the recycling rate, that is the amount of waste paper used as raw material in the production of paper, was 36%. Today, the rate is 22% owing to market conditions, government policies which discriminate against recycled materials, and the prohibitive labor cost of hand sorting waste paper. See, Midwest Research Institute, PAPER RECYCLING—THE ART OF THE POSSIBLE, 1970-1985, (March 1973) at 4.

²¹Michigan Water Resources Commission, BIOLOGICAL SURVEY OF THE KALAMAZOO RIVER, at 67-8, (April 1972).